

4(PRTS)

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1 Apparatus and method for treatment of chemical and  
2 biological hazards

3

4 The present invention relates to an apparatus for the  
5 treatment of hazardous materials specifically prions,  
6 chemical and biological agents. The invention further  
7 relates to a method for using such an apparatus.

8

9 The risks associated with contamination caused by  
10 chemical and biological agents of various kinds are  
11 well known. Medical equipment and surgical instruments  
12 are required to be sterilised to eliminate a growing  
13 range of infectious agents including more recently  
14 prions implicated in new variant Creusfeld Jacob  
15 Disease (nvCJD). Proteins exhibit huge variation in  
16 structure. However, they are formed in similar ways  
17 and thus display certain structural elements and  
18 characteristics that are common. The primary structure

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1 of proteins is determined by the amino acid sequence  
2 and pendant side groups. The amino acid chains are  
3 then folded to form various secondary structures  
4 designated as  $\alpha$ -helices or  $\beta$ -sheets. Secondary  
5 structure is determined by the folding of the amino  
6 acid chains and interactions between the various side  
7 groups. Further associations may also form, depending  
8 on the protein's environment. For example different  
9 hydrophilic and hydrophobic groups or areas within the  
10 protein molecule are sensitive to the medium in which  
11 the molecule may be suspended. The prion protein plays  
12 an essential role in the pathogenesis of a group of  
13 sporadic, genetically determined and infectious fatal  
14 degenerative diseases, referred to as prion diseases,  
15 or transmissible encephalopathys (TSE's), affecting the  
16 central nervous system of humans and other mammals.  
17 The cellular prion protein is encoded with a single  
18 copy gene, highly conserved across mammalian species.  
19 In prion diseases this protein undergoes conformational  
20 changes involving a shift from  $\alpha$ -helix to  $\beta$ -sheet  
21 structure. The structures of the proteins, both native  
22 and rogue, have been extensively investigated. The one  
23 of most interest and immediate impact to humans is the  
24 protein associated with nvCJD. What is unusual about  
25 the protein that is associated with TSEs is the extreme  
26 robustness it exhibits. This is thought to be due its  
27  $\beta$ -sheet structure. Prions are known to survive  
28 temperatures in excess of 300 °C. Such proteins thus

1 represent present particular problems in terms of their  
2 transmission and destruction. The nvCJD prion is known  
3 to have a high affinity for stainless steel and other  
4 metals posing significant difficulties for the  
5 sterilisation of medical equipment, such as surgical  
6 instruments. At the same time, considering hazards  
7 unrelated to the medical field, chemical and biological  
8 agents, such as those used as weapon materials, pose  
9 significant handling and disposal risks.

10

11 For the purposes of the present application, the term  
12 "hazardous material" means any organic material that  
13 may be inimical to human well being and as such may be  
14 classed as a chemical or biological hazard. "Hazardous  
15 material" includes, but is not restricted to, viral  
16 material, bacterial material, prions, proteins, lipids,  
17 chemical and biological agents / material with  
18 associated organophosphate bases, organic waste or by-  
19 products associated with pharmaceutical processes and  
20 blood products, and further includes all of said agents  
21 in isolation and when found within, on the surface of  
22 or bonded to other material, instruments or equipment.  
23 The term "target material" is used throughout in  
24 reference to a "hazardous material" which is to be  
25 treated according to the method of the invention.

26

27 The term "treatment" is used in its broadest form and  
28 encompasses the deactivation and destruction of  
29 hazardous material. Relatively minor modifications to

1 the structure or conformation of a particular agent may  
2 be sufficient to render it inactive without the need  
3 for the agent to be destroyed or decomposed into  
4 constituent elements.

5

6 While some methods for treating such agents are known,  
7 these typically involve the use of reagents which are  
8 themselves difficult to handle and which have  
9 associated safety issues. Fluorine and ozone for  
10 example may be effective in catalysing such processes,  
11 but create significant handling problems and are not  
12 suited to use in an open bath apparatus. Furthermore  
13 some prior art processes are required to be carried out  
14 at very high temperatures and / or pressures. The  
15 apparatus used in such processes is necessarily complex  
16 and expensive in light of the associated handling  
17 difficulties.

18

19 There remains therefore a need for a method for the  
20 deactivation or destruction of prions, chemical and  
21 biological agents, which is effective, efficient and  
22 broadly applicable. There is a particular need for an  
23 apparatus and a treatment method that can be used to  
24 sterilise or decontaminate equipment and instruments  
25 that may have come into contact with hazardous  
26 material. The present invention as set out below  
27 provides such an apparatus and a method for its use.

28

1 Accordingly, in a first aspect the present invention  
2 provides apparatus for treating hazardous material and  
3 for decontaminating items that may have come into  
4 contact with such material. In its broadest form such  
5 apparatus comprises an operator accessible treatment  
6 vessel or chamber and a light source capable of  
7 irradiating a catalyst within the treatment vessel or  
8 chamber with a predetermined wavelength.

9

10 A first embodiment of the invention provides an  
11 apparatus, for batch treatment of hazardous material,  
12 comprising a treatment vessel for holding material to  
13 be treated; a light source for irradiating the contents  
14 of the treatment vessel; circulation or agitation means  
15 and progress and / or by-product monitoring means. The  
16 treatment vessel may comprise a 'glove box' type lid  
17 facilitating manipulation of the bath contents by an  
18 operator. An automatic light source cut-off may be  
19 incorporated in order to enhance operator safety.

20

21 A second embodiment provides an apparatus comprising a  
22 treatment vessel having one or more decontamination  
23 trays for holding hazardous material or items to be  
24 treated, a light source for irradiating the contents of  
25 the treatment vessel, medium distribution means for  
26 circulating a carrier medium within and / or through  
27 the apparatus and by-product monitoring means.

28

1 A third embodiment provides an apparatus comprising a  
2 holding tank for holding a carrier medium; a catalyst  
3 hopper for holding a catalyst; a mixing vessel for  
4 mixing the carrier medium and the catalyst; one or more  
5 treatment chambers each having a housing which contains  
6 a plurality of treatment beds and a light source; and a  
7 distribution header for controlling the flow of carrier  
8 medium and catalyst into the treatment chambers.  
9 Preferably, each treatment bed comprises means for  
10 inducing turbulent flow within the carrier medium  
11 flowing therein.

12

13 A second aspect of the present invention provides a  
14 method for the deactivation and / or destruction of  
15 hazardous material comprising the step of irradiating  
16 the hazardous material in the presence of a catalyst  
17 with light having a wavelength in the range of 310 nm  
18 to 400 nm. The method of the invention causes  
19 sufficient chemical modification of the hazardous  
20 material so as to deactivate or destroy it.

21

22 Preferably, the catalyst is TiO<sub>2</sub> in either rutile or  
23 anatase form and preferably the method is carried out  
24 at ambient temperature (of between about 15 to 35 °C)  
25 and pressure (of between about 1 to 5 bar).

26

27 The method may be carried out in any water based  
28 carrier medium that is compatible with the target  
29 material and catalyst. Preferably the carrier medium

1 is water. Judicious choice of treatment medium is  
2 required in order to ensure reliable and effective  
3 treatment. In particular when considering the  
4 treatment of objects or instruments contaminated with  
5 prions for example the physical characteristics of the  
6 apparatus and method should facilitate a suitable  
7 reaction interface. This involves consideration of the  
8 composition and viscosity of the carrier medium and the  
9 path-length of the apparatus such that the target  
10 material, catalyst and photons from the light source  
11 are brought together in a manner suitable to effect  
12 treatment. It follows that a medium that is relatively  
13 low in viscosity and has appropriate optical  
14 characteristics (over the wavelength(s) of the light  
15 source) is desirable. In other words, the viscosity  
16 must be such as to allow the bringing together of the  
17 target material and the catalyst and the configuration  
18 of the apparatus and the optical characteristics of the  
19 medium must allow sufficient transmission of light to  
20 the target / catalyst reaction site.

21

22 Thus, the present invention provides for the treatment  
23 hazardous material such as prions linked with human or  
24 animal nvCJD in both  $\alpha$  and  $\beta$  forms and for treatment of  
25 instruments and equipment that may have been  
26 contaminated with said material. The method, and  
27 apparatus for implementing it, are also applicable to  
28 the destruction of chemical agent material, typically

1 organophosphate based systems, as typified by VX or  
2 Sarin, but additionally blistering and choking agents  
3 as typified by Mustard Gas and Tear Gas. Depending  
4 upon the conditions employed, the invention provides  
5 for total destruction of some hazardous material by  
6 breaking it down into its constituent parts,  
7 principally carbon dioxide, nitrogen, water and  
8 inorganic salts, or alternatively provides for  
9 sufficient modification of target materials so as to  
10 render them inactive. The invention can also  
11 deactivate or destroy many other biohazards, viral and  
12 bacteriological material, and many commonly  
13 industrially produced organic materials. Furthermore,  
14 the method of the invention can be employed to  
15 decontaminate materials, equipment, instruments and the  
16 like which may have come into contact with hazardous  
17 material.

18

19 The method of the invention represents an efficient  
20 means of deactivating and / or destroying of hazardous  
21 material under mild conditions on a batch basis.  
22 Further advantages of the invention are described  
23 below.

24

25 The various aspects of the invention are described in  
26 detail below with reference to the accompanying  
27 drawings in which:

28

1 Figure 1 shows a first embodiment of an apparatus  
2 according to the invention;  
3 Figure 2 shows a second embodiment of an apparatus  
4 according to the invention;  
5 Figure 3 shows a third embodiment of an apparatus  
6 according to the invention; and  
7 Figures 4 and 5 are more detailed views of the  
8 treatment chamber of the embodiment shown in Figure 3.

9

10 In the drawings similar reference numerals have been  
11 used to designate components common to each of the  
12 alternative embodiments.

13

14 In its broadest form the invention provides a  
15 decontamination method for the treatment of hazardous  
16 material comprising the step of irradiating the  
17 hazardous material in the presence of a catalyst, with  
18 light of a suitable wavelength, to deactivate or  
19 destroy the target material through photocatalytic  
20 oxidative processes. In general terms, the apparatus  
21 of the present invention comprises (i) a treatment  
22 chamber in which the catalyst and the target material  
23 may be irradiated with light of a suitable wavelength  
24 (and energy) and (ii) a light source capable of  
25 producing the desired wavelength. The light source  
26 wavelength and intensity may be adjusted to optimise  
27 the process depending upon the nature of the target  
28 material and the choice of catalyst. A liquid carrier,  
29 preferably a water based medium, is used to introduce

1 hazardous material into the treatment chamber for  
2 irradiation.  
3  
4 Without being bound by theory, the invention is  
5 considered to be the result of an interaction of light  
6 energy (photons), the catalyst and water elements that  
7 forms hydroxyl radicals which cleave sections of, or  
8 links in, molecules of the target material ('primary  
9 effects'). The action of UV light contributes directly  
10 to the breakdown of target materials through photolysis  
11 of molecules present. In conjunction with the  
12 formation of hydroxyl radicals hydrogen peroxide ( $H_2O_2$ )  
13 is also produced. This oxidising agent assists and  
14 speeds the decontamination process cycle. The primary  
15 effects of hydroxyl radicals allow secondary processes  
16 (such as attack by  $H_2O_2$ ) to act upon vulnerable parts of  
17 the molecules. The ultimate result is the break down  
18 of hazardous material into simple (safe) moieties,  
19 formation of inorganic salts within the carrier medium  
20 and production of off-gases, such as  $CO_2$ .  
21  
22 The method of the invention employing highly reactive  
23 hydroxyl radicals and  $H_2O_2$  produced through irradiation  
24 of a suitable catalyst can be utilised to oxidise prion  
25 proteins decomposing them to  $NO_x$ ,  $CO_2$ , water and various  
26 inorganic salts. Attack on a prion protein molecule by  
27 a hydroxyl radical causes selective breakage of  
28 multiple bond linkages, thus permanently altering the  
29 crucial relationship between amino acid units and

1 inducing changes to their proper attachment and  
2 alignment to each other (and to associated components  
3 such as carbohydrates and possibly lipids). This  
4 effect changes the spatial configuration of the prion  
5 protein impacting upon its ability to reproduce  
6 properly. It is possible that even small alterations  
7 in the protein composition and / or configuration are  
8 sufficient to impede biological activity of a prion  
9 molecule. Any alteration in the structural make-up and  
10 configuration reduces the resistance of the prion to  
11 further oxidative processes, such as attack by H<sub>2</sub>O<sub>2</sub>,  
12 thus increasing the rate of complete oxidation of the  
13 molecule.

14

15 Contact between the hydroxyl radical / hydrogen  
16 peroxide production interface and the target material  
17 on the equipment / instruments or the like, using the  
18 water based carrier medium with the catalyst, is  
19 maximised. This may be addressed by ensuring that the  
20 catalyst within the water carrier is migrated to the  
21 interface using suitable circulation or entraining  
22 processes. Minimising the spatial offset in this  
23 manner increases the effects of the short-lived  
24 radicals produced upon irradiation. Spatial offset  
25 distance is further aided through the use of small  
26 catalytic particulate (3 - 5 microns).

27

1 Prior cleaning of gross material make take place within  
2 the decontamination train, that minimises the volume of  
3 material to be decontaminated, and improves throughput.

4

5 Increasing the intensity of irradiation and / or  
6 increasing the surface area of catalyst irradiated can  
7 increase radical production. Additional catalyst may  
8 be introduced to speed the process and replace catalyst  
9 extracted from the waste stream.

10 The catalyst may be any photosensitive material, which  
11 allows, through illumination with light of a suitable  
12 wavelength, a reaction with the associated hazardous  
13 material to occur. Suitable catalyst materials include  
14 for example TiO<sub>2</sub>, TiO<sub>3</sub>, ZnO, CdS, CdSe, SnO<sub>2</sub>, WO<sub>3</sub>, Fe<sub>2</sub>O<sub>3</sub>  
15 and Ta<sub>2</sub>O<sub>5</sub>. An example of a preferred catalyst is TiO<sub>2</sub>.  
16 Irradiation of the catalyst produces active sites (on  
17 what is in effect a semiconductor surface) causing  
18 water absorbed to the surface to be oxidised. Highly  
19 reactive hydroxyl radicals formed in this manner react  
20 with (and ultimately decompose) the target material  
21 present in the system.

22

23 The catalyst may be used in any form that provides  
24 suitable contact with the target material. For  
25 example, the catalyst may be dispersed in the carrier  
26 medium or it may be coated onto or mixed with the  
27 various materials to be decontaminated or destroyed. A  
28 catalyst module such as a column or tower coated with

1 catalyst material may be employed. Alternatively, the  
2 catalyst may be coated onto internal surfaces of the  
3 apparatus, enhancing robustness and self-cleaning  
4 capability. Recovery of the catalytic material for  
5 reuse, increasing efficiency of the process, may be  
6 provided for as described below.

7

8 While light in the range of 310 nm to 400 nm is  
9 preferred, the wavelength of light employed may vary  
10 depending upon the catalyst used, the medium used and  
11 the nature of the target material. The wavelength to  
12 be used may be selected based on the absorption  
13 characteristics of the target material, thus increasing  
14 efficiency. As photo-generated hydroxyl radicals are  
15 the primary agents responsible for the decontamination  
16 / destruction processes various parameters may be  
17 changed to optimise the effect upon any given target  
18 material. The selected wavelength may be produced for  
19 example using a standard mercury lamp in conjunction  
20 with a suitable filter.

21

22 The method of the invention degrades target materials  
23 ultimately reducing them to simple reaction products  
24 such as CO<sub>2</sub>. The evolution of CO<sub>2</sub> or any other reaction  
25 product can thus be used to monitor the degree and rate  
26 of the process. Suitably off-gas production or target  
27 material break down may be monitored using techniques  
28 such as Raman spectroscopy, mass spectrometry, *in vitro*

1 tests or other known techniques appropriate to any  
2 particular hazardous material.

3

4 Characteristics of the method of the invention are  
5 detailed in Table 1, together with comparable data for  
6 various prior art methods. The 'efficiency' values  
7 indicate the rate and effectiveness of electron  
8 transfer during the treatment process.

Catalyst	Efficiency (eV)	Medium	Output toxicity	Temp (°C)	Pressure (bar)	Power
TiO <sub>2</sub> (present invention)	3.34	Water	Very low	<36	<10	Low
Ag (II)*	1.98	Nitric acid	High	-90	10	High
Ruthenium*	1.8	H <sub>2</sub> SO <sub>4</sub>	High	-90	10	High
Chlorination*	1.3	Water	High	-40	<10	Low
H <sub>2</sub> O <sub>2</sub> **	2.00	Water	Low	<36	<10	Low

1

2   Table 1.                 \*Indicates prior art process; \*\*Hydrogen  
 3                                 peroxide not a catalyst as such - included  
 4                                 for comparison purposes only.

5

6   Prior art methods (other than those detailed in Table  
 7   1) include hydrogenation and methods employing molten  
 8   metals or supercritical water. These additional  
 9   methods all pose significant hazards themselves due to  
 10   the operating conditions required in order to be  
 11   effective (for example, all three require temperatures  
 12   in excess of 600 °C; and hydrogenation and  
 13   supercritical water methods operate at pressures of  
 14   about, or in excess of, 100 bar). Treatment with  
 15   fluorine, possibly the strongest oxidising agent known,  
 16   is also effective, but extremely difficult and  
 17   dangerous to handle.

1 The method of the invention provides an effective and  
2 efficient process for the deactivation and / or  
3 destruction of hazardous material, on batch or  
4 continuous basis, while overcoming the shortcomings of  
5 some prior art methods in terms of operational  
6 requirements and characteristics. The present  
7 invention facilitates decontamination treatments to be  
8 carried out under ambient temperature and pressure  
9 conditions through a method and apparatus which has  
10 minimal moving parts, is easy to maintain and operate  
11 and which is readily scalable.

Class of Compound	Examples
Alkanes	Methane; pentane; heptane; n-dodecane; cyclohexane, paraffin
Haloalkanes	mono-, di-, tri-, and tetrachloromethane; dichloropropane Pentachloroethane; di and tribromoethane; 1,2-dichloropropane
Aliphatic Alcohols	methanol; ethanol; n- and iso-propanol; butanol; penta-1, 4-diol
Aliphatic Carboxylic Acids	methanoic, ethanoic; trichloroacetic; butyric; oxalic
Alkenes	propene; cyclohexene
Haloalkenes	di-, tri- and tetra-chloroethene; hexafluoropropene
Aromatics	benzene; naphthalene, Tributyl Phosphate
Haloaromatics	chloro and bromobenzene; chlorobenzenes; halophenols
Phenols	phenol; hydroquinone; catecol; resorcinol; cresol, nitrophenol
Aromatic Carboxylic Acids	benzoic; phthalic; salicyclic
Polymers	Polyethylene; PVC
Surfactants	Polyethylene glycol; p-nonyl phenyl ether; sodium dodecyl benzene sulphonate; paraxon; malathion
Herbicides	methyl viologen; atrazine; simazine; bentazon
Pesticides	DDT; parathion; lindane, monocrotophos
Dyes	methylene blue; rhodamine B; methyl orange; fluorescein
Explosives	Trinitrotoluene
Cyanotoxins	Microcystins, Anatoxin-a
Bacteria	E.Coli., Serratia marcescens,
Proteins	

Table 2

1 Table 2 lists compounds successfully destroyed using  
2 the present invention. Tributyl phosphate, appearing  
3 in the 'Aromatics' class, is a simulant for nerve  
4 agents.

5

Material	Concentration (% v/v)	Wavelength (nm)	Time (min)	Efficiency (%)
Methanol	0.1	385 +/- 10	20	99.5
Paraffin	0.1	385 + / - 10	40	99.75
Benzene	0.1	380 + / - 10	60	99.9

6 Table 3.

7

8 Table 3 details a number of test materials and the  
9 conditions under which they were treated. In each case  
10 treatment was carried out at atmospheric pressure and  
11 at room temperature. The treatment efficiency (which  
12 in the case of the three test materials corresponds to  
13 destruction of the compounds in question) was measured  
14 using spectrophotometric techniques.

15

16 The specific embodiments of an apparatus according to  
17 the invention described below may each be provided with  
18 a circulation system, a catalyst feed mechanism, and a  
19 catalyst recovery system. In addition there may be a  
20 flushing mechanism to remove excess free catalyst  
21 deposits from the cleaned instruments or tools and  
22 materials prior to final removal and drying. Larger  
23 units having the same basic unit structure may be

1 complemented by material towers coated with the  
2 catalyst through which the contaminated material in the  
3 water-based matrix is allowed to percolate, thus  
4 increasing exposure of the contaminants to the catalyst  
5 and UV sources.

6

7 Prior cleaning of gross material make take place within  
8 the decontamination train, that minimises the volume of  
9 material to be decontaminated, and improves throughput.

10

11 A first embodiment of an apparatus according to the  
12 invention is shown schematically in Figure 1. The  
13 apparatus comprises a treatment chamber or bath (1), a  
14 light source (2), a circulation pump (3), an off-gas  
15 monitor / treatment unit (8), a catalyst recovery  
16 system (4) and a holding tank (5). A catalyst hopper  
17 (6) and a medium storage unit (7) for storing the  
18 catalyst and carrier medium prior to use are also  
19 provided. This first embodiment has been designed for  
20 small quantity throughput of, for example, surgical  
21 instruments for decontamination or for destruction of  
22 small quantities of target material. Manual  
23 manipulation of items in the treatment chamber may be  
24 facilitated through use of a glove-box type lid (9).  
25 This apparatus is designed for operation by medical  
26 staff in for example medical or dental practices.

27

28 Catalyst material and carrier medium are introduced  
29 into the holding tank (5), from the catalyst hopper (6)

1 and the medium storage unit (7) respectively, and from  
2 there into the treatment chamber (1). The catalyst is  
3 typically suspended in the carrier medium and suitable  
4 stirring means may be provided in order to ensure that  
5 suspension is maintained and that the suspension  
6 circulates within the chamber (1). The contaminated  
7 equipment or target material (not shown) is placed in  
8 to the bath; the lid closed and interlocks (not shown)  
9 engaged before the process commences. In order to  
10 maintain the catalyst in suspension within the carrier  
11 medium during the process, the medium is circulated  
12 through the system by using suitable means. This  
13 facilitates maximum irradiation of the catalyst  
14 simultaneously allowing the catalyst particles to  
15 contact the interface with the target material. A  
16 circulating pump (3) is used for the removal of  
17 catalyst via the catalyst recovery system (4) at the  
18 end of the process run. The catalyst recovery system  
19 (4), typically takes the form of a cyclone separator.  
20 The level of catalyst in the system is monitored via  
21 the process controller (not shown) and adjusted to the  
22 required level. The carrier medium is circulated  
23 within the bath (1) during the  
24 decontamination/destruction process and may be replaced  
25 or replenished from the medium storage unit (7) or via  
26 the catalyst recovery system (4). The process  
27 controller (not shown) is used to monitor the overall  
28 process, including monitoring off-gas production within  
29 the off-gas monitor/treatment system (8). The off-gas

1 monitoring system (8) provides the means by which the  
2 primary process status is monitored. The destruction  
3 of organic elements produces CO<sub>2</sub>, when no further CO<sub>2</sub>  
4 production is detected the treatment process may be  
5 regarded as complete. The residual CO<sub>2</sub> given off is  
6 collected by use of an active charcoal filter fitted  
7 into the off-gas system (8). Sampling can be  
8 facilitated in order to allow for conformity *in vitro*  
9 testing, spectroscopic analysis or the like to take  
10 place. Once completion of the process has been  
11 confirmed the used carrier medium can be disposed of in  
12 a recognised manner and the apparatus may be flushed  
13 with fresh medium. The flushing process enables all the  
14 areas within the apparatus that may have been  
15 contaminated by target material to be cleaned, although  
16 the system is inherently self-decontaminating. The  
17 carrier medium within treatment chamber (1) is then  
18 topped-up prior to next usage and the medium in the  
19 holding tank (7) replaced. While the method of the  
20 invention may generally be carried out at, or close to,  
21 atmospheric pressure, materials may be passed through  
22 the apparatus under higher pressure particularly during  
23 catalyst recovery and / or cleaning stages.

24

25 Access to the treatment chamber (1) for this activity  
26 may be provided by a glove box lid arrangement (9).  
27 This allows for function (if necessary), dismantling  
28 and scrubbing of instruments or equipment to remove  
29 stubborn or hidden contaminants. These are

1 subsequently circulated and destroyed in the treatment  
2 chamber during the treatment process. Safety  
3 interlocks may be employed to minimise any risks to  
4 personnel during operation, particularly when  
5 introducing target material in to the apparatus.  
6 Switching means are provided for deactivating the light  
7 source automatically when the bath lid (9) is opened.

8

9 Prior cleaning of gross material make take place within  
10 the decontamination train, that minimises the volume of  
11 material to be decontaminated, and improves throughput.

12

13 A second embodiment is shown schematically in Figure 2.  
14 This apparatus is designed for use in hospitals or  
15 larger clinics with high throughput of surgical  
16 instruments for decontamination. It is designed for  
17 operation by dedicated staff with training in the  
18 decontamination of surgical instruments and equipment.

19

20 The apparatus comprises a treatment chamber (1) having  
21 decontamination trays (10) an ultraviolet light source  
22 (2) and a medium distribution system (11). Catalyst  
23 from the catalyst hopper (6) and / or a catalyst  
24 recovery system (4) are introduced into a holding tank  
25 (5). The contaminated equipment or product is placed  
26 in the decontamination trays (10) and the trays (10)  
27 are lowered into the treatment chamber (1). The lid is  
28 closed and interlocks engaged before the process is  
29 allowed to start. In order to maintain the catalyst in

1 suspension within the medium, the medium is circulated  
2 by means of a circulation pump (3) and a medium  
3 distribution system (11) having a plurality of rotating  
4 spray heads (not shown). The distribution system (11)  
5 creates a pressure jet effect that develops a catalyst  
6 laden mist or aerosol within the treatment chamber (1)  
7 which facilitates optimum contact / interaction between  
8 the UV light, catalyst and target material on the  
9 contaminated instruments. The carrier medium drains to  
10 the bottom of the treatment chamber (1) where it is  
11 collected in a circulation header tank (12) which in  
12 turn feeds the circulation pump (3). At the end of the  
13 treatment process any excess catalyst is recovered from  
14 the medium via a catalyst recovery system (4). As  
15 described above, a process control (not shown) is  
16 provided to monitor progress of the treatment by means  
17 of off-gas monitor / treatment system (8). Upon  
18 completion of the treatment process, the lid is  
19 removed, trays raised and the decontaminated  
20 instruments removed.

21

22 The medium, including suspended catalyst, may be  
23 circulated directly through the treatment chamber (1)  
24 from the holding tank (5) during the decontamination  
25 process or via the catalyst treatment unit (4) during  
26 the catalyst recovery cycle. Carrier medium is sampled  
27 for conformity / quality maintenance as described in  
28 relation to the previous embodiment. The medium level  
29 within the circulation header tank (12) is monitored

1 prior to and during operation and is topped-up as  
2 required.

3

4 The third embodiment, shown schematically in Figure 3  
5 with details of the treatment chamber arrangement shown  
6 in Figures 4 and 5, is designed for either high or low  
7 volume destruction of high level bio-hazards such as  
8 chemical or biological agent materials, prion  
9 contaminated material or the like (and may be adapted  
10 to handle solid, liquid or gas phase hazardous  
11 materials). It is envisaged that such a system would  
12 be operated in a restricted area by dedicated and  
13 suitably trained staff.

14

15 The apparatus comprises a series treatment chambers (1)  
16 the number and configuration of which may be adapted  
17 depending upon the nature and quantity of material to  
18 be treated. The target material in a suitable pre-  
19 prepared state is introduced from a target material  
20 hopper (13) under control of metering means (14) into a  
21 mixing vessel (15). The carrier medium is fed in to  
22 the mixing vessel (15) from the circulation header tank  
23 (12) by the circulation pump (3) and catalyst is added  
24 from a catalyst hopper (6). The pre-treatment  
25 preparation of the target material may include but need  
26 not be limited to the breaking down of solids into  
27 smaller particles, the suspension of solid particles in  
28 a liquid or the absorption of a gas into a liquid. The  
29 target material, medium and catalyst mixture cascades

1 into distribution header (16) from which it enters the  
2 treatment chambers (1). This method of controlling the  
3 flow of the mixture removes any potential pressure  
4 other than the hydrostatic head determined by the  
5 relationship between the mixing vessel (15) and the  
6 distribution header (16). Each treatment chamber (1)  
7 comprises a housing that contains a series of tray-like  
8 treatment beds and a light source (2). The treatments  
9 beds are designed to maximise the time which the  
10 carrier medium, catalyst and target material mixture is  
11 exposed to the UV light, as well as promoting the  
12 formation of turbulent flow. Typically each treatment  
13 bed comprises of a series of channels (17) running back  
14 and forth across the bed, each channel (17) containing  
15 a textured surface (18) designed to induce turbulent  
16 flow within the mixture. Control of the flow in this  
17 manner prevents the catalyst and target material from  
18 being shielded (as could occur in a laminar flow  
19 situation) and maximises irradiation effectiveness.  
20 The treatment beds are configured with a light source  
21 (2), optionally shrouded with a mirror, directly  
22 overhead. Each treatment bed further comprises a  
23 transparent top plate, typically made from quartz or  
24 some other material having suitable light transmission  
25 characteristics. The treatment mixture is circulated  
26 around the system until the process has been completed  
27 or for a suitable duration as dictated by the operator.  
28 Any suspended solids, catalyst and other waste products

1 are removed via a catalyst / waste treatment system (4)  
2 for storage prior to final disposal.

3

4 Specific modifications may be introduced into the  
5 carrier medium composition and flow control in order to  
6 create the necessary environment for the target  
7 material to be suspended within the medium. For  
8 example, rotary, ultrasonic or other stirring /  
9 agitation means make be incorporated into the  
10 apparatus.

11

12 The process is controlled using a suitable process  
13 monitoring and control system. This includes  
14 monitoring the off-gas status by means of an off-gas  
15 monitoring / treatment system (8). The off-gas  
16 monitoring / treatment system (8) also provides a means  
17 for the monitoring and collection / treatment of  
18 gaseous reaction products such CO<sub>2</sub>, NO<sub>x</sub>, SO<sub>x</sub> and the  
19 like. In order to treat these off-gases specific  
20 equipment such as scrubbers and absorbers may be  
21 provided. As before suitable analytical techniques can  
22 be employed to monitor the course of the treatment and  
23 the content of used waste products and used carrier  
24 medium.

25

26 The invention is not limited to the embodiments herein  
27 described which can be varied in construction and  
28 detail.